1. SCOPE

1.1 SCOPE. This DOE Standard illustrates and suggests practices and procedures for conducting a nuclear criticality safety (NCS) program at U.S. Department of Energy (DOE) nonreactor nuclear facilities having significant quantities of fissionable materials. These DOE practices and procedures are relevant to NCS program administration and oversight, NCS personnel selection and training, performance of NCS evaluations and analyses, emergency response, and programmatic control of processes, storage, procedures, hardware, and software. Throughout the text of this document, the term "fissionable material," used for concision, refers to the term that is specifically relevant to criticality safety concern, "significant quantity of fissionable material."

1.2 APPLICATION. This DOE Standard applies to government contractors operating DOE nonreactor nuclear facilities having significant quantities of fissionable materials (unirradiated and irradiated) in process, storage, or transport outside a nuclear reactor core. This application extends to processing and burying of fissionable material wastes and handling or processing and storing of reactor fuel in storage pools.

1.3 STRATEGY AND INTENT. It is DOE policy to use National and International Consensus Standards (e.g., ANSI/ANS Standards) when such standards are available to meet DOE needs. DOE Standards (not to be confused with National and International Consensus Standards) are comprehensive guidance documents to assist in implementation of DOE Rules and Orders through use of good practices. Their comprehensiveness precludes their full applicability to all sets of conditions, since a good practice for one set of conditions may be an unnecessary, or a poor, practice for a similar, but not identical, set of conditions.

DOE Standards generally should not be used to develop audit check-lists. This DOE Standard is not a requirements document and **shall** not be used as an auditing standard. It is intended only to provide guidance, but to meet this intention nuclear criticality safety professionals are expected to be familiar with its content. Requirements for DOE nuclear criticality safety programs are found in higher level documents, e.g., Policy, Rule, Order, and Manual. These documents, e.g., the Order or the Manual, may invoke National and International Consensus Standards. Use of the word "shall" (i.e., as the statement of a requirement) in this DOE Standard is only to maintain consistency with higher level documents and **shall** not be used to impose requirements beyond those in higher level documents, except for use of the term "**shall**" in this paragraph.

Because the work performed at the different DOE sites is diverse (viz., hands-on unshielded fissionable material operations at some sites and remote shielded operations at other sites), this DOE Standard, being relevant to such work, is also diverse. Hence, it is comprehensive and covers most of the areas of responsibility pertaining to conducting a nuclear criticality safety program. To this end, information in this document has been gathered eclectically, therefore it is inappropriate to use this document in its entirety either for any one site or for any single application. Its intent, therefore, is to present a comprehensive text of good practices for nuclear criticality safety, and to depend on good judgment in both engineering and management to be the principal determinant for applicability of these good practices. While even a comprehensive text of good practices cannot address every need, it can serve as a source of ideas to address differing needs as they arise.

Imbalance of detail is an expected characteristic of a comprehensive document that draws eclectically from diverse sources. In this DOE Standard, such imbalance, while present, is manifest

by too much detail in some areas rather than too little detail in any one area. As a fault, therefore, it is one of form rather than content, and a conservative fault, at that.

1.4 DOCUMENT REFERENCES. Some DOE documents (e.g., DOE Orders) referenced in this DOE Standard may have been revised or cancelled by the time of issuance of the standard. Citation of references in this standard is intended to identify information that is relevant to this standard whether such information is found in the reference or in its revision or replacement.

1.5 ANSI/ANS Series-8 Standards. The basic elements and control parameters of programs for nuclear criticality safety at DOE must meet the requirements of specified ANSI/ANS Series-8 standards. Therefore, in the interest of clarity, familiar phraseology directly from these standards is sometimes used in this DOE Standard. Where such phraseology is used without attribution, failure to attribute is unintentional.

2. APPLICABLE DOCUMENTS

2.1 DOE DOCUMENTS. Information from the following DOE Orders, Standards, and Guides was used in the development of this standard.

2.1.1 DOE 1300.2A. DEPARTMENT OF ENERGY TECHNICAL STANDARDS PROGRAM, of 5-19-92, provides requirements for the development and application of technical standards in Department of Energy facilities, programs, and projects.

2.1.2 DOE 1324.2A. RECORDS DISPOSITION, of 9-13-88, contains procedures for the retention and disposition of records.

2.1.3 DOE 5000.3B. OCCURRENCE REPORTING AND PROCESSING OF OPERATIONS INFORMATION, of 1-19-93, establishes a system for reporting unusual occurrences having programmatic significance.

2.1.4 DOE 5480.3. SAFETY REQUIREMENTS FOR THE PACKAGING AND TRANSPORTATION OF HAZARDOUS MATERIALS, HAZARDOUS SUBSTANCES, AND HAZARDOUS WASTES, of 7-9-85, describes the requirements for packaging and transportation of hazardous materials, hazardous substances, and hazardous wastes.

2.1.5 DOE 5480.4. ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION STANDARDS, of 5-15-84, specifies the application of mandatory ES&H standards to DOE operations.

2.1.6 DOE 5480.11. RADIATION PROTECTION FOR OCCUPATIONAL WORKERS, of 12-21-88, provides radiation protection standards and program requirements for operations with respect to the protection of the worker from ionizing radiation.

2.1.7 DOE 5480.18B. NUCLEAR FACILITY ACCREDITATION TRAINING PROGRAM, of 8-31-94, institutionalizes a performance-based training process for DOE Category A reactors and high-hazard and selected moderate-hazard non-reactor nuclear facilities.

2.1.8 DOE 5480.19. CONDUCT OF OPERATIONS REQUIREMENTS FOR DOE FACILITIES, of 7-9-90, which establishes requirements dealing with the conduct of operations for DOE operators.

2.1.9 DOE 5480.20A. PERSONNEL SELECTION, QUALIFICATION, TRAINING, AND STAFFING REQUIREMENTS AT DOE REACTOR AND NON-REACTOR NUCLEAR FACILITIES, of 2-20-91, describes the requirements for personnel involved in the operation, maintenance, and technical support of DOE-owned Category A and B reactors and non-reactor nuclear facilities.

2.1.10 DOE 5480.21. UNREVIEWED SAFETY QUESTIONS, of 12-24-91, establishes the means by which Unreviewed Safety Questions (USQs) are identified and the means of resolution of USQs.

2.1.11 DOE 5480.22. TECHNICAL SAFETY REQUIREMENTS, of 2-25-92, establishes DOE's nuclear facility technical safety requirements.

2.1.12 DOE 5480.23. NUCLEAR SAFETY ANALYSIS REPORTS, of 4-10-92, which establishes uniform requirements for the preparation and review of safety analyses.

2.1.13 DOE 420.1, Section 4.3. FACILITY SAFETY, of 10-13-95, establishes DOE's nonreactor nuclear facility nuclear criticality safety program.

2.1.14 DOE 5484.1. ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION INFORMATION REPORTING REQUIREMENTS, of 2-24-81, establishes the requirements and procedures for reporting and investigating matters of significance for the protection of environment, safety, and health at DOE operations.

2.1.15 DOE 5500.2B. EMERGENCY CATEGORIES, CLASSES, AND NOTIFICATION AND REPORTING REQUIREMENTS, of 4-30-91, establishes requirements for the coordination and direction of planning, preparedness, and response to operational emergencies.

2.1.16 DOE 5500.3A. PLANNING AND PREPAREDNESS FOR OPERATIONAL EMERGENCIES, of 4-30-91, which establishes requirements for the development of site-specific emergency plans and procedures at nuclear facilities.

2.1.17 DOE 5700.6C. QUALITY ASSURANCE, of 8-21-91, describes DOE's quality assurance program requirements for nuclear facilities and activities.

2.1.18 DOE 6430.1A. GENERAL DESIGN CRITERIA, of 04-6-89, contains the criteria for the design and construction of DOE facilities.

2.1.19 DOE-STD-3007-93. GUIDELINES FOR PREPARING CRITICALITY SAFETY EVALUATIONS AT DEPARTMENT OF ENERGY NON-REACTOR NUCLEAR FACILITIES, of December 1993, contains guidelines that should be followed when preparing Criticality Safety Evaluations that will be used to demonstrate the safety of operations performed at Department of Energy (DOE) Non-Reactor Nuclear Facilities.

2.1.20 DOE-STD-3013-94. CRITERIA FOR SAFE STORAGE OF PLUTONIUM METALS AND OXIDES, of December 1994 provides for safe storage (for at least 50 years or until final disposition) of plutonium metals, selected alloys, and stabilized oxides that contain a minimum of 50 weight-percent plutonium.

2.1.21 DOE/TIC-11603-REV. 1. NONREACTOR NUCLEAR FACILITIES: STANDARDS AND CRITERIA GUIDE, of September 1986, is a source document that identifies standards, codes, and guides that address the nuclear safety considerations at nuclear facilities.

2.2 OTHER FEDERAL DOCUMENTS. Information from the following other federal documents was used in the development of this standard.

2.2.1 Code of Federal Regulations (CFR).

2.2.1.1 Title 10, Part 70 of the CFR. *Domestic Licensing of Special Nuclear Material* describes the procedures and criteria for the issuance of licenses to receive title to, own, acquire, deliver, receive, possess, use, and initially transfer special nuclear materials.

2.2.1.2 Title 10, Part 71 of the CFR. *Packaging and Transportation of Radioactive Material* describes the requirements for obtaining Nuclear Regulatory Commission (NRC) approval of packaging and shipment of licensed material.

2.2.1.3 Title 10, Part 830 of the CFR. *Nuclear Safety Management* describes requirements for preventing the uncontrolled release of radioactivity to the environment, inadvertent criticality, limiting and monitoring facility staff exposure to radiation and radioactivity, and protecting the public from exposure to radiation and radioactive contamination.

2.2.2 NRC Regulatory Commission Documents. Information from the following NRC Regulatory Guides was used in the development of this standard.

2.2.2.1 NRC Regulatory Guide 3.1. *Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material* describes a method of using borosilicate-glass Raschig rings as a neutron absorber for criticality safety control in plants processing special nuclear materials.

2.2.2.2 NRC Regulatory Guide 3.4. *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* describes acceptable procedures for the prevention of criticality accidents in the handling, storing, processing, and transporting of fissionable materials outside of nuclear reactors.

2.2.2.3 NRC Regulatory Guide 3.34. *Assumptions Used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in a Uranium Fuel Fabrication Plant* describes methods used for performing analyses to assess the risk to public health and safety resulting from postulated nuclear criticality accidents in uranium fuel fabrication and processing plants.

2.2.2.4 NRC Regulatory Guide 3.35. *Assumptions Used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in a Plutonium Processing and Fuel Fabrication Plant* describes methods used for performing analyses to assess the risk to public health and safety resulting from postulated nuclear criticality accidents in plutonium processing and fuel fabrication plants.

2.2.2.5 NRC Regulatory Guide 3.68.

2.2.2.6 NRC Regulatory Guide 8.12. *Criticality Accident Alarm Systems* describes the specifications for use of criticality alarms where there is a potential hazard to workers from nuclear criticality accidents.

2.2.2.7 NUREG/BR-0167. *Software Quality Assurance Program and Guidelines*, using industry standards, provides guidance in the development and maintenance of software.

2.2.2.8 NUREG/CR-1278, SAND80-0200,RX,AN. *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications* provides some useful information for the performance of human reliability analyses.

2.2.2.9 NUREG/CR-4639, EEG-2458. *Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR): Summary Description* provides some useful human reliability data for the performance of human reliability analyses, primarily plant-specific reactor data from public domain sources.

2.3 NON-GOVERNMENT DOCUMENTS.

2.3.1 American National Standards Institute (ANSI).

2.3.1.1 ANSI/ANS-8.1-1983,R88. *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* provides basic criteria and limits for operations with fissionable materials outside reactors except for critical experiments. The standard also provides requirements for establishing the validity and areas of applicability of any calculational method used in assessing nuclear criticality safety.

2.3.1.2 ANSI/ANS-8.3-1986. *Criticality Accident Alarm System* provides the performance criteria for detecting nuclear criticality accidents.

2.3.1.3 ANSI/ANS-8.5-1986. *Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material* describes the chemical and physical environment for usage, properties of the rings and packed vessels, maintenance inspection procedures, and criticality operating limits for solution systems containing ^{235}U, ^{239}Pu, or ^{233}U.

2.3.1.4 ANSI/ANS-8.6-1983,R88. *Safety in Conducting Subcritical Neutron-Multiplication Measurements in Situ* provides safety guidance for conducting subcritical neutron-multiplication measurements where physical protection of personnel against the consequences of a criticality accident is not provided.

2.3.1.5 ANSI/ANS-8.7-1975,R87. *Guide for Nuclear Criticality Safety in the Storage of Fissile Materials* provides mass and spacing limits for the storage of uranium containing greater than 30 wt % ^{235}U, for ^{233}U, and for plutonium as metals and oxides.

2.3.1.6 ANSI/ANS-8.9-1987. *Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials* provides criteria and data based on experiments and calculations applicable to homogeneous aqueous solutions.

2.3.1.7 ANSI/ANS-8.10-1983,R88. *Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement* provides criteria for the prevention of nuclear accidents in facilities with shielding and confinement and a definition of the adequacy of the shielding and confinement required.

2.3.1.8 ANSI/ANS-8.12-1987,R93. *Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors* provides single parameter limits for fissionable units of simple shape containing the three principal fissile nuclides.

2.3.1.9 ANSI/ANS-8.15-1981,R87. *Nuclear Criticality Control of Special Actinide Elements* provides single parameter limits for maintaining nuclear criticality safety of special actinide elements.

2.3.1.10 ANSI/ANS-8.17-1984,R89. *Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors* addresses LWR fuel rods and units outside reactor cores.

2.3.1.11 ANSI/ANS-8.19-1984,R89. *Administrative Practices for Nuclear Criticality Safety* provides criteria for the administration of a nuclear criticality safety program for operations outside of reactors in which there exists a potential for criticality accidents.

2.3.1.12 ANSI/ANS-8.20-1991. *Nuclear Criticality Safety Training* provides criteria for the administration of a nuclear criticality safety training program for personnel who manage, work in, or work near facilities where the potential exists for a criticality accident outside of reactors, though it does not apply to the training of nuclear criticality safety staff.

2.3.1.13 ANSI/ANS-8.21-1995. *Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors* provides guidance for using fixed neutron absorbers integrally in nuclear facilities and fissionable material process equipment outside reactors to provide criticality safety control.

2.3.1.14 ANSI/ANS-10.3-1986. *Guidelines for the Documentation of Digital Computer Programs* presents guidelines for the documentation of digital computer programs prepared for scientific and engineering applications with the objective to facilitate effective selection, usage, transfer, conversion, and modification of computer programs.

2.3.1.15 ANSI/ANS-10.4-1987. *Guidelines for the Verification and Validation of Scientific and Engineering Computer Programs for the Nuclear Industry* provides guidelines for the verification and validation (V&V) of scientific and engineering computer programs developed for use by the nuclear industry with the objective to identify activities that will improve the reliability of scientific and engineering computer programs and reduce the risk of incorrect application.

2.3.1.16 ANSI/IEEE-Std-500-1984. *IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear-Power Generating Stations* provides data useful for performing equipment reliability analyses.

2.3.2 Industry Related Reference Documents.

2.3.2.1 LA-10294-MS. *Guide to Radiological Accident Considerations for Siting and Design of DOE Nonreactor Nuclear Facilities*, of January 1986, provides the experienced safety analyst with accident analysis guidance in greater detail than is possible in Department of Energy Orders.

2.3.2.2 ANS-9, *GLOSSARY of Terms in Nuclear Science and Technology*, American Nuclear Society Standards Subcommittee ANS-9 on Nuclear Terminology and Units, Harry Alter, Chairman, La Grange Park, Illinois, 1986.

2.3.2.3 LA-11627-MS, *GLOSSARY of Nuclear Criticality Terms*, Hugh C. Paxton, Los Alamos National Laboratory, Los Alamos, New Mexico, October 1989.

2.3.2.4 PNL-SA-4868, Rev. 5, *Anomalies of Nuclear Criticality*, E. D. Clayton, Pacific Northwest Laboratory, Richland, Washington, June 1979, provides discussions and explanations of deviations from commonly accepted rules of criticality behavior.

2.3.2.5 LA-3366 (Rev), *Criticality Control in Operations with Fissile Material*, H. C. Paxton, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, November 1972, provides criticality data and makes them understandable in terms of simple reactor physics concepts to help develop intuition for conditions to be avoided during operations.

2.3.2.6 NUREG-0492, *Fault Tree Handbook*, U.S. Nuclear Regulatory Commission, January 1981, is a textbook on the fault tree technique for acquiring information about a system.

2.3.2.7 DOE/NCT--04, *A Review of Criticality Accidents*, William R. Stratton (revised by David R. Smith), Los Alamos National Laboratory, Los Alamos, New Mexico, March 1989, provides discussions of forty-one criticality accidents and the characteristics of their prompt power excursions.

2.3.2.8 *Criticality and Fissionability Properties of Selected Actinide Nuclides*, Los Alamos National Laboratory, Los Alamos, New Mexico, to be issued, provides information concerning the nuclear properties of selected nuclides of the first ten of the fourteen actinide elements -- thorium through einsteinium.

2.3.2.9 LA-10860-MS, *Criticality Dimensions of Systems Containing ^{236}U, ^{239}Pu, and ^{233}U, 1986 Revision*, H. C. Paxton and N. L. Pruvost, Los Alamos National Laboratory, Los Alamos, New Mexico, July 1987, provides a compilation of critical data obtained from experiments performed during the period of 1945 through 1985, supplementing TID-7016 (section 2.3.2.10 of this standard).

2.3.2.10 TID-7016, Rev. 3, *Nuclear Safety Guide*, Los Alamos National Laboratory, Los Alamos, New Mexico, to be issued, provides general guidance information related to nuclear criticality safety principles, experience, and practice.

2.3.3 Journal Articles, and Meetings and Conference Proceedings.

A bibliography of technical journal articles and of technical meeting and conference proceedings relevant to nuclear criticality safety can be found in Appendix H.

3. TERMS AND DEFINITIONS. The following provides terms and definitions used within this standard. The word *shall* is used to denote a requirement, the word *should* to denote a recommendation, often of a higher level document, and the word *may* to denote permission, neither a requirement nor a recommendation, except when used in its other context, meaning contingency, i.e., possibility. A more general understanding of the roles of requirements and recommendations in this standard can be obtained from sections 1.3 and 5.2.

Phrases or words that are italicized are defined or listed elsewhere in the terms and definitions of this section.

3.1 ABSORBER, NEUTRON - A material with which *neutrons* significantly interact by reactions, resulting in their disappearance as free particles.

3.2 ABSORPTION, NEUTRON - A neutron-induced reaction, including *fission*, in which the neutron disappears as a free particle. The absorption cross section is designated σ_a. See *capture, neutron; cross section, neutron.*

3.3 ACCIDENT, CREDIBLE - Those accidents with an estimated probability of occurrence $>10^{-6}$/year.

3.4 ACCIDENT, CRITICALITY (also NUCLEAR CRITICALITY ACCIDENT) - The release of energy as a result of accidentally producing a self-sustaining or divergent *fission chain reaction.*

3.5 ACCIDENT, DESIGN BASIS (DBA) - Accidents that are postulated for the purpose of establishing functional requirements for safety significant structures, systems, components, and equipment.

3.6 ALARM SYSTEM, CRITICALITY ACCIDENT (CAS) - A system capable of providing an immediate emergency evacuation alarm signal (usually audible but may be visible) after detecting (usually by the detection of gamma or neutron, or both, radiation) a *criticality accident.*

3.7 ALBEDO, NEUTRON - The probability under specified conditions that a neutron entering into a region through a surface will return through that surface.

3.8 ALPHA PARTICLE - A ^{4}He nucleus, usually emitted during a nuclear transformation.

3.9 ANALYSIS, NUCLEAR CRITICALITY SAFETY (NCSA) - The documented rationale demonstrating the nuclear criticality safety of a nonreactor nuclear facility that contains fissionable material. The analysis is developed by the nonreactor nuclear facility management, engineering design personnel, facility operations supervision, and nuclear criticality safety personnel. It provides sufficient descriptions of the facility equipment, fissionable material processes, and operational controls to identify the normal and contingent abnormal operating conditions of the facility. The analysis may reference or contain the technical computational or comparative *nuclear criticality safety evaluation* results that provide the bases of subcritical operating values for the normal and abnormal (contingent) conditions of facility operations or processes.

3.10 AREA, ARCHIVE STORAGE - An area in a computer system's storage that contains copies of source and executable code for superseded versions of the software and the master copy of the source and the current executable version.

3.11 AREA, DEVELOPMENT STORAGE - An area in computer storage in which software is stored during development without the possibility of inadvertent production use. Upon completion of the software change, the software is transferred to the Migration Area. Access to this area is limited to that necessary for development. The Development Storage Area resides in the individual developer's computer space.

3.12 AREA, MIGRATION STORAGE - An area in computer storage in which software verification tests are performed in a simulated production environment. Upon completion of the verification testing and with the approval of the Software System team, the software is transferred to the Production Storage Area. Access to the Migration Storage Area is limited to that necessary for testing.

3.13 AREA, PRODUCTION STORAGE - An area in a computer storage from which the software is invoked by authorized software users. Only the current version of the software will be in the Production Storage Area, and only the *system administrator* and a designated back-up will have write access to this area if proper software quality assurance procedures are followed.

3.14 AREAL DENSITY - The total mass of *fissionable material* per unit area projected perpendicularly onto a plane. For an infinite, uniform slab, it is the product of the slab thickness and the concentration of *fissionable material* within the slab.

3.15 AREAS OF APPLICABILITY - The ranges of material compositions, geometric arrangements and other factors within which the bias and its corresponding uncertainty of a calculational method is established.

3.16 BARN - A unit of area used in expressing nuclear *cross sections*; 1 barn = 10^{-24} cm^2.

3.17 Be/X - Conventionally, the atomic ratio of beryllium to ^{235}U, ^{239}Pu, or ^{233}U in a solution or mixture. Where there is more than one *fissile* species, the ratios are specified separately.

3.18 BETA PARTICLE - An electron, of either negative or positive charge, that has been emitted by an atomic nucleus or neutron in a nuclear transformation.

3.19 BIAS, CALCULATIONAL - A measure of the systematic disagreement between the results calculated by a method and experimental data. The uncertainty in the bias is a measure of both the precision of the calculations and the accuracy of the experimental data. See DOE Order 420.1, Section 4.3.

3.20 BIRDCAGE - A container and attached cage-like structure for maintaining a safe distance between a body of *fissionable material* and other objects (including other bodies of *fissionable material*), which, if brought too close, might give rise to *criticality*.

3.21 BUCKLING - The eigenvalue of the Helmholtz equation (either B_m^2 or B_g^2). Algebraic expressions can be used to relate material (B_m^2) or geometric (B_g^2) characteristics of critical, subcritical, or supercritical fissionable material systems.

3.22 BURST, PROMPT - Usually refers to the pulse or *spike* of energy from fissions produced by a *prompt burst reactor*.

3.23 C/X - Conventionally, the atomic ratio of carbon to ^{235}U, ^{239}Pu, or ^{233}U in a solution or mixture. Where there is more than one *fissile* species, the ratios are specified separately.

3.24 CALCULATIONAL METHOD - The mathematical equations, approximations, assumptions, associated numerical parameters, such as neutron cross sections, and calculational procedures that yield the calculated results.

3.25 CAPTURE, NEUTRON - Neutron absorption not leading to fission or other neutron production. The capture cross section is designated σ_c. See *absorption, neutron; cross section, neutron*.

3.26 CENT - A unit of reactivity equal to one-hundredth of the increment between delayed criticality and prompt criticality (a *dollar*).

3.27 CERTIFICATION - The process by which contractor nuclear facility management provides written endorsement of the satisfactory achievement of qualification of a person for a position.

3.28 CHAIN REACTION, NUCLEAR FISSION - A sequence of *nuclear fission* reactions in which the fissions are induced by neutrons emerging from preceding fissions. Depending on whether the number of fissions directly induced by neutrons from one fission is on the average less than, equal to, or greater than unity, the *nuclear fission chain reaction* is convergent (*subcritical*), self-sustaining (*critical*), or divergent (*supercritical*).

3.29 CODE, EXECUTABLE - The machine-language program that is the output after translation (compiling) and linking of the source code.

3.30 CODE, SOURCE - The original mnemonic or high-level statement versions of a program. The starting information or "source" from which the final "object" (machine language or executable code) is derived.

3.31 CONFIGURATION CONTROL TEST - Periodic testing of the production version of software to determine if unauthorized changes have occurred.

3.32 CONFIRMATION - The performance of audits, inspections, surveillance activities, and other assessments of compliance with regulatory or nuclear criticality safety program requirements, analysis/evaluation requirements, and other requirements.

3.33 CONSERVATISM - Simplifying approximations and assumptions in safety analyses and evaluations and their applications that increase the safety margin above the required minimum.

3.34 CONTAINER - See *packaging*.

3.35 CONTINGENCY - A credible but unlikely change in a condition/control important to the nuclear criticality safety of a *fissionable material operation* that would, if it occurred, reduce the number of barriers (either administrative or physical) that are intended to prevent a nuclear criticality accident.

3.36 CONTROL AREA, FISSIONABLE MATERIAL (FMCA) - *Fissionable material* operating or storage areas where physical and procedural controls are applied to maintain *nuclear criticality safety*.

3.37 CONTROL - The apparatus, processes, and mechanisms that, when manipulated could affect the chemical, physical, metallurgical, or any other process of the nonreactor nuclear facility in such a manner as to affect *nuclear criticality safety*.

3.38 CONTROLLED DOCUMENT - A document whose content is maintained uniform by an administrative control system.

3.39 CONTROLS, ACTIVE-ENGINEERED - Those active means for ensuring nuclear criticality safety control methods. These means of control include active electrical, mechanical, and hydraulic hardware that sense a process variable important to nuclear criticality safety and provide automatic action to secure the system to a safe condition without requiring human intervention.

3.40 CONTROLS, ADMINISTRATIVE - Those administrative means for assuring nuclear criticality safety control methods. These means of control include organization and management, procedures, record keeping, assessment, and reporting necessary to ensure the *nuclear criticality safety* of a *nonreactor nuclear facility*.

3.41 CONTROLS, PASSIVE-ENGINEERED - Those means for ensuring nuclear criticality safety control methods that do not require human intervention or electrical or mechanical reaction to off-specification conditions. These means of control take advantage of natural forces, such as gravity, physical chemistry limitations, and inherent physical characteristics, such as rigidity and structural integrity of cylindrical geometries, and limited compressibility of solids. These means of control include devices to prevent unsafe accumulations of fissionable material within a unit such as siphon breaks, filters, and pipe blanks between process vessels and spacing devices such as birdcages, racks, and stanchions between containers as well as fixed neutron poisons within vessels such as Raschig rings or between containers.

3.42 CORE - That part of a *fissionable material* system containing most or all of the fissionable material, as distinguished from a *reflector*.

3.43 CREDIBILITY - See *credible*.

3.44 CREDIBLE - Offering reasonable grounds for being believed on the basis of commonly accepted engineering judgment.

3.45 CRITICAL - Fulfilling the condition that a medium capable of sustaining a *nuclear fission chain reaction* has an *effective multiplication factor*, k_{eff}, equal to unity. (A *nuclear reactor* is critical when the rate of neutron production, excluding neutron sources whose strengths are not a function of fission rate, is equal to the rate of neutron loss.)

3.46 CRITICAL INFINITE CYLINDER - For a specified *fissionable material* and surrounding *reflector*, the infinitely long cylinder with a diameter that would be *critical*.

3.47 CRITICAL INFINITE SLAB - For a specified *fissionable material* and *reflector* on each surface, the slab of infinite lateral dimensions with a thickness that would be *critical*.

3.48 CRITICALITY ACCIDENT SCENARIO, POTENTIAL - A credible sequence of events that could lead to a *criticality accident*, which starts with an initiating event, such as a process upset, valving error, pluggage of a line, and/or operator error, followed by events involving failure or loss of

criticality safety control (preventive) measures. Each potential criticality accident scenario represents a single path of events leading to a criticality accident, and all scenarios together encompass the total probability of criticality accident thereby permitting the evaluation of total risk in the *facility*.

3.49 CRITICALITY SAFETY, NUCLEAR (NCS) - Protection against the consequences of an inadvertent *nuclear fission chain reaction*, preferably by preventing the reaction.

3.50 CRITICALITY - The condition of being *critical*.

3.51 CROSS SECTION (σ), NEUTRON MICROSCOPIC - A measure of the probability of a specified interaction between an incident *neutron* and a target particle or system of particles. It has the dimension of area and may be visualized as the area normal to the direction of an incident particle, which has to be attributed to the target particle to account geometrically for its interaction with the incident particle. It is commonly expressed in *barns*. Such cross sections include but are not limited to *neutron capture* (σ_c), *fission* (σ_f), neutron scatter (σ_s), and neutron absorption (σ_a).

3.52 CROSS SECTION (Σ), NEUTRON MACROSCOPIC - For a pure nuclide, it is the product of the *neutron microscopic cross section* for a particular reaction and the number of target nuclei per unit volume, giving it units of inverse length; for a mixture of nuclides, it is the sum of such products.

3.53 D/X - Conventionally, the atomic ratio of deuterium to ^{235}U, ^{239}Pu, or ^{233}U in a solution or mixture. Where there is more than one *fissile* species, the ratios are specified separately.

3.54 DECAY, RADIOACTIVE - A spontaneous nuclear transformation in which particles or gamma radiation is emitted, in which x-radiation is emitted following orbital electron capture, or in which the nucleus undergoes *spontaneous fission*.

3.55 DELAYED CRITICALITY - State of a *fissionable material* system such that the *multiplication factor*, k_{eff}, equals 1 as the steady-state condition.

3.56 DELAYED NEUTRONS - Neutrons emitted when the beta-decay of a fission product leads to a sufficiently highly excited state in the daughter nucleus that neutron emission is energetically possible. The time delay, relative to emission of *prompt neutrons*, is from somewhat less than 1 second to about 60 seconds.

3.57 DESIGN FEATURES - Active or passive features that are necessary to prevent, or reduce the probability of, a criticality accident.

3.58 DETECTION SYSTEM, CRITICALITY ACCIDENT (CDS) - A *criticality accident* detection system (usually gamma or neutron, radiation detection, or both) without an immediate emergency evacuation alarm, the purpose of which is to provide sufficient response time to allow for appropriate process-related mitigation, recovery actions, and possible delayed evacuation alarm if radiation exposures could be effectively limited by such actions.

3.59 DOABLE - A doable condition or instruction is one that is capable of being obeyed or performed, respectively. That is, a fissionable material operation, storage, or transport condition, limit, specification, instruction, etc. that can be measured or evaluated, and proper responses taken to obey the condition or properly perform the instruction.

3.60 DOLLAR - A unit of *reactivity* equal to the increment between *delayed criticality* and *prompt criticality* for a fixed chain reacting system.

3.61 DOSE, PROMPT - The total neutron and gamma dose imparted from the nearly instantaneous nuclear fission process.

3.62 DOUBLE-CONTINGENCY ANALYSIS - A double-contingency analysis is an analysis of potential criticality accident scenarios for the purpose of demonstrating compliance with the *double-contingency principle* by identifying appropriate barriers and means of control.

3.63 DOUBLE-CONTINGENCY PRINCIPLE (APPLICATION) - Process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. Protection shall be provided by either (i) the control of two independent process parameters (which is the preferred approach, when practical, to prevent common-mode failure), or (ii) a system of multiple controls on a single process [nuclear] parameter. The number of controls required upon a single controlled process parameter shall be based upon control reliability and any features that mitigate the consequences of control failure. In all cases, no single credible event or failure shall result in the potential for a criticality accident, except where single contingency operations are permissible, as presented in paragraph 5.1 of ANSI/ANS-8.10-1983,R88. This exception applies to operations with shielding and confinement (e.g., hot cells or other shielded facilities). Double contingency shall be demonstrated by documented evaluations.

3.64 EMERGENCY ACTION LEVELS - Radiological dose rates; specific contamination levels of airborne, waterborne, or surface deposited concentrations of radioactive materials or specific instrument indications (including their rates of change) that may be used as thresholds for initiating such specific emergency measures as designating a particular class of emergency, initiating a notification procedure, or initiating a particular protective action.

3.65 EMERGENCY ASSESSMENT ACTIONS - Assessment actions are those actions taken during or after a perceived accident to obtain and process information that is necessary to implement corrective actions.

3.66 EMERGENCY CENTRAL CONTROL POINT - A place from which emergency response actions are directed.

3.67 EMERGENCY COORDINATOR - The person with authority to initiate immediately and independently any emergency actions including providing protective action recommendations to government authorities.

3.68 EMERGENCY CORRECTIVE ACTIONS - Those measures taken to terminate or mitigate the consequences of a perceived nuclear criticality accident.

3.69 EMERGENCY DRILL - A supervised instruction period intended to test, develop, and maintain skills in a particular operation anticipated during an emergency. A drill is often a component of an exercise.

3.70 EMERGENCY EXERCISE - An event that tests the integrated capability and a major portion of the basic elements existing within emergency preparedness plans and organizations.

3.71 EMERGENCY IMMEDIATE EVACUATION ZONE - The area surrounding a nuclear criticality accident location that must be evacuated as soon as a nuclear accident alarm signal is heard, seen, or otherwise discerned.

3.72 EMERGENCY OPERATIONS CENTER - The Emergency Operations Center (EOC) is an accessible area set aside for providing an assembly area for operational support personnel during an emergency situation.

3.73 EMERGENCY PLANNING ZONE (EPZ) - The area surrounding a specific facility, operation, and/or activity for which special planning and preparedness efforts are required to ensure that prompt and effective protective actions can be taken to minimize the risk to onsite personnel and the general public, in the event of a criticality accident requiring evacuation.

3.74 EMERGENCY PROTECTIVE ACTIONS - Those emergency measures taken after a nuclear criticality accident to prevent or minimize radiological exposures to persons that would be likely to develop if the actions were not taken.

3.75 EMERGENCY RECOVERY ACTIONS - Those related actions taken after the emergency condition has been terminated.

3.76 EMERGENCY TECHNICAL STAFF - Those persons whose specific skills and experience may be called upon during the development or implementation of emergency planning, emergency response, or recovery operations.

3.77 EVALUATION, NUCLEAR CRITICALITY SAFETY (NCSE) - A documented demonstration of the technical computational basis or comparative evaluation between operational or postulated conditions and experimental data that provides the bases for the subcritical operating values addressed in the *nuclear criticality safety analyses*.

3.78 EVENT, ANTICIPATED - Events with an estimated probability of occurrence between 1/year and 10^{-2}/year. These events are of moderate frequency and may occur once or more during the lifetime of a facility.

3.79 EVENT, CREDIBLE - Events with an estimated probability of occurrence greater than 10^{-6}/year.

3.80 EVENT, EXTREMELY UNLIKELY - Events with an estimated probability of occurrence between 10^{-4}/year and 10^{-6}/year. These events are not expected to occur in the lifetime of a facility.

3.81 EVENT, INCREDIBLE - Events with an estimated probability of occurrence less than 10^{-6}/year. These events are considered to be of extremely low probability of occurrence or non-mechanistic hypothetical events.

3.82 EVENT, UNLIKELY - Events with an estimated probability of occurrence between 10^{-2}/year and 10^{-4}/year. These events are not expected but may occur during the lifetime of a facility.

3.83 EXCURSION, NUCLEAR - An episode during which the *fission* rate of a *supercritical* system increases, peaks, and then decreases to a low value. Also, see *accident, criticality*.

3.84 EXCURSION PERIOD (T) - The reciprocal coefficient of time (t), where fission power in a *nuclear excursion* increases as $e^{(t/T)}$ before a *quenching mechanism* becomes effective.

3.85 EXCURSION, PROMPT POWER - A *nuclear excursion* as the result of configuring *fissionable material* to achieve *prompt criticality*. In general, a sharp power *spike* followed by a plateau that may be interrupted by smaller spikes.

3.86 EXERCISE, TABLE-TOP - An event in which re-entry, rescue, etc. actions are simulated that test the emergency management's capability to cope with a nuclear criticality accident.

3.87 EXPONENTIAL COLUMN - A subcritical block or cylinder of *fissionable material* with an independent *neutron* source at one end. Under appropriate conditions, the response of a neutron detector decreases exponentially with distance from the source. From the logarithmic rate of this decrease and lateral dimensions of the column, critical dimensions of an unreflected assembly of the material may be deduced.

3.88 EXPOSURE - A measure of the ionization produced in air by *x-rays* or *gamma radiation*; the sum of electric charges on all ions of one sign in a small volume of air when all electrons liberated by photons are completely stopped, per unit mass of the air. Note that exposure refers to the environment, not absorbing material. The unit of exposure is the *roentgen*. Alternatively, exposure is the incidence of radiation on living or inanimate material.

3.89 FACILITY, NONREACTOR NUCLEAR - An operational area (e.g., building, holding, storage, or disposal area) dedicated to activities or operations (handling, storing, or transporting) that involve radioactive or fissionable materials, or both, in such form and quantity that a nuclear hazard potentially exists to the employees or the general public. Included are activities or operations that

1. produce, process, or store radioactive liquid or solid waste, fissionable materials, or tritium;
2. conduct separations operations;
3. conduct irradiated and/or fissionable materials inspection, fuel fabrication, decontamination, or recovery operations;
4. conduct fuel enrichment operations; or
5. perform environmental remediation or waste management activities involving radioactive materials.

Incidental use and generation of radioactive materials in a facility operation (e.g., check and calibration sources, use of radioactive sources in research and experimental and analytical laboratory activities, electron microscopes, and X-ray machines) would not ordinarily require the facility to be included in this definition. Accelerators and reactors and their operations are not included.

3.90 FAVORABLE GEOMETRY - Geometric constraint of *fissionable material* in which *subcriticality* is maintained under anticipated conditions. Examples are limited diameter of pipes intended to contain fissile solution, or limited volumes of solution containers.

3.91 FISSIBLE NUCLIDE - A *nuclide* that cannot sustain a *nuclear fission chain reaction* with *slow neutrons* but is only capable of sustaining a *nuclear fission chain reaction* by interaction with *fast neutrons*, provided the effective fast neutron production cross section ($\bar{\nu}\bar{\sigma}_f$) exceeds the effective

fast neutron absorption cross section ($\bar{\sigma}_a$). Such nuclides include ^{231}Pa, ^{234}U, ^{237}Np, ^{238}Pu, ^{240}Pu, ^{242}Pu, ^{241}Am, ^{243}Am, ^{244}Cm, ^{246}Cm, ^{250}Cf, and ^{252}Cf.

3.92 FISSILE NUCLIDE - A *nuclide* capable of sustaining a *fission* chain reaction by interaction with *slow neutrons*, provided the effective neutron production cross section ($\bar{\nu}\bar{\sigma}_f$) exceeds the effective absorption cross section ($\bar{\sigma}_a$). Such nuclides include ^{232}U, ^{233}U, ^{235}U, ^{239}Pu, ^{241}Pu, ^{242m}Am, ^{243}Cm, ^{245}Cm, ^{247}Cm, ^{249}Cf, ^{251}Cf, and ^{254}Es.

3.93 FISSION, NUCLEAR - The division of a heavy nucleus into two (or, rarely, more) parts with masses of equal order of magnitude, usually accompanied by the emission of neutrons, gamma radiation, and, rarely, small charged nuclear fragments. Although some fissions take place spontaneously, neutron-induced fissions are of major interest in criticality safety. The neutron fission cross section is designated σ_f, and ν is the number of neutrons emitted per fission.

3.94 FISSION PRODUCTS - Nuclides produced by *nuclear fission* or by the subsequent *radioactive decay* of *nuclides* formed in this manner.

3.95 FISSION, SPONTANEOUS - *Nuclear fission* that occurs without the addition of particles or energy to the nucleus.

3.96 FISSION YIELD, EXCURSION - The total number of *fissions* in a *nuclear excursion*.

3.97 FISSIONABLE EQUIVALENT MASS (FEM) - That gram mass of a fissionable material having the same mass ratio to its minimum critical mass as that mass ratio of a different fissionable material gram mass to its minimum critical mass. For example, given materials x and y having minimum critical masses of m_{cx} and m_{cy}, the FEM mass of x, m_x, is directly proportional to the grams of y, m_y, times the minimum critical mass of material x divided by the minimum critical mass of material y (i.e., $m_x = [m_y \bullet m_{cx}]/m_{cy}$). The FEM enables comparison of a quantity of one fissionable nuclide to a quantity of a second, or reference, fissionable nuclide based on their minimum subcritical mass limits. If more than one nuclide is present, their FEMs (in terms of the reference) can be summed.

3.98 FISSIONABLE MATERIAL - A material of any *nuclides* capable of sustaining a *nuclear fission chain reaction*. For nuclear criticality safety purposes, such materials are composed of *fissionable nuclides* but may include nonfissionable nuclides. Such material may be fissionable material only by virtue of its form, configuration, and environment. That is: natural uranium as mined, processed, and transported in bulk form is not fissionable material; however, natural uranium as fabricated into reactor fuel element pellets or rods may be considered as fissionable material if handled in a processing or operating environment where the pellets or rods could be adequately moderated to create a critical system. This definition is intended strictly for this standard.

3.99 FISSIONABLE MATERIAL HANDLER - An individual officially designated by installation management to manipulate or handle significant quantities of *fissionable materials*, or manipulate the controls of equipment used to produce, process, transfer, store, or package significant quantities of such fissionable materials.

3.100 FISSIONABLE NUCLIDE - Any *nuclide* capable of undergoing neutron induced *fission*. For nuclear criticality safety purposes, such nuclides include the *fissile* or *fissible nuclides* but may also include nuclides such as ^{227}Ac, ^{228}Th, ^{229}Th, ^{230}Th, ^{232}Th, ^{233}Pa, ^{236}U, ^{238}U, and ^{239}Np.

3.101 GAMMA RADIATION - Short-wavelength electromagnetic radiation emitted in the process of nuclear transition or particle annihilation.

3.102 GEOMETRY CONTROL - Physically controlling the shape, dimensions, and configuration of *fissionable material* or of equipment containing fissionable material to maintain such systems safety subcritical.

3.103 GRADED APPROACH - A process of performing a *nuclear criticality safety evaluation* that acknowledges different levels of effort and documentation are appropriate for different complexities of *fissionable material operations* and the associated methods and controls applied to maintain subcriticality and safety.

3.104 GRAY - A unit of *absorbed dose*; 1 Gy = 1 J/kg = 100 *rad*.

3.105 GUIDES, PROTECTIVE ACTION (PAGs) - The projected radiological doses or dose commitment values to individuals in the general population that warrant protective action following a release of radioactive material. Protective actions would be warranted provided the reduction in individual dose expected to be achieved by carrying out the protective action is not offset by excessive risks to individual safety in taking the protective action. The PAG does not include the dose that has unavoidably occurred prior to the assessment.

3.106 H/X - Conventionally, the atomic ratio of hydrogen to ^{235}U, ^{239}Pu, or ^{233}U in a solution or hydrogenous mixture. Where there is more than one *fissile* species, the ratios are specified separately.

3.107 HAZARD - A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to a facility or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation). "Potentially hazardous" is redundant. Note that a hazardous facility is not necessarily a high-*risk* facility.

3.108 HIGH ENRICHED URANIUM (HEU) - Uranium having isotopic contents of ^{235}U or ^{233}U greater than or equal to 20 weight percent. HEU generally refers to 93 weight percent ^{235}U.

3.109 INCIDENT, NUCLEAR CRITICALITY SAFETY - A loss of control or change in process condition as specified within the NCSA.

3.110 INHOUR - A unit of reactivity that, when added to a delayed-critical system, would produce a period of one hour; now seldom used.

3.111 INSTALLATION, NONREACTOR NUCLEAR - A contractor-operated DOE site comprising one or more *nonreactor nuclear facilities*.

3.112 IONIZING RADIATION - Any radiation consisting of directly or indirectly ionizing particles, *photons*, or a mixture or both. *X-rays* and the radiations emitted in *radioactive decay* are examples.

3.113 IRRADIATION - Exposure to *ionizing radiation*.

3.114 k_{eff} - See MULTIPLICATION FACTOR, EFFECTIVE.

3.115 k_∞ - See MULTIPLICATION FACTOR, INFINITE.

3.116 LIMIT, ADMINISTRATIVE - Self-imposed procedural limit relating to *nuclear criticality safety* (See *limits, routine operating).*

3.117 LIMIT, CRITICALITY SAFETY (CSL) - The point (limit) beyond which safety cannot be ensured. The safety limit is a limit on *process parameters* affecting *nuclear parameters* associated with those barriers that are necessary for the intended facility function and that are required to guard against a *criticality accident.*

3.118 LIMIT, ROUTINE OPERATING - The procedural limit placed on a controlled *process parameter* during routine operations. The breach of an *operating limit* could, but not necessarily will, result in the violation of the *limiting conditions for operation,* violation of the *double-contingency principle.* Typically, there is a range of relatively minor process upsets that do not cause the loss of *double-contingency.*

3.119 LIMIT, UPPER SUBCRITICAL (USL) - The limiting value of system *reactivity* beyond which subcriticality cannot be ensured (e.g., k_{eff}). The upper subcritical limit only allows for uncertainties in the calculations and experimental data used in its derivation.

3.120 LIMITING CONDITION FOR OPERATION (LCO) - The minimum acceptable conditions, functional capabilities, or performance levels that must exist to initiate or continue operations.

3.121 LIMITING CONTROL SETTING (LCS) - The setting on a process variable associated with safety systems that control the facility function and will prevent exceeding the associated *criticality safety limit.*

3.122 LIMITING SAFETY SYSTEM SETTING (LSSS) - An active process instrumentation or alarm setting that is intended to prevent a system from reaching the *safety limit* through the activation of safety class items or the initiation of operator action. Limiting Safety System Settings will not exist for many *fissionable material operations* due to the absence of continuously monitored process variables important to nuclear criticality safety. This is especially true in instances where nuclear criticality safety relies on limited interaction of many units within an array. Spacing is ensured by the construction of properly spaced *fissionable material containers,* but no active process instrumentation is used to monitor the spacing among the units.

3.123 LINEAR ENERGY TRANSFER (LET) - The average energy lost by an *ionizing radiation* per unit distance of its travel in a medium. A high LET is generally associated with *protons, alpha particles,* and *neutrons,* whereas a low LET is associated with *x-rays,* electrons, and *gamma rays.*

3.124 LOW ENRICHED URANIUM (LEU) - Uranium having isotopic contents of ^{235}U or ^{233}U less than 20 weight percent. LEU generally refers to ≤ 5 weight percent ^{235}U.

3.125 MAINFRAME COMPUTER - For purposes of this procedure, a computer in which file control is achieved by access rules within the operating system rather than by physical control of storage media.

3.126 MANAGEMENT, LINE/PRODUCTION - The organizational unit that accepts the direct responsibility for, and exercises authority over, the application of nuclear safety to their operations.

3.127 MANAGER, FACILITY OPERATIONS - The person whose facility warrants nuclear criticality safety consideration and controls, and who should, therefore, accept responsibility for the day-to-day nuclear criticality safety of his/her facility.

3.128 MANAGER, FUNCTIONAL SYSTEM - The person appointed to represent specific Nuclear Criticality Safety Departments in the development and implementation of software configuration control plans for defined software system(s).

3.129 MODEL - A representation of the actual physical parameters used in a calculation.

3.130 MODERATOR - A material used to reduce neutron energy by scattering neutrons without appreciable neutron capture.

3.131 MULTIPLICATION FACTOR, EFFECTIVE (k_{eff}) - Physically, the ratio of the total number of neutrons produced during a time interval (excluding neutrons produced by sources whose strengths are not a function of fission rate) to the total number of neutrons lost by absorption and leakage during the same interval. Mathematically (computationally), that eigenvalue number (Lagrange multiplier if defined as production-to-loss ratio) which, when divided into the actual mean number of neutrons emitted per fission in an assembly of materials, would make the calculated result for the nuclear chain reaction of that assembly artificially critical.

3.132 MULTIPLICATION FACTOR, INFINITE (k_∞) - The k_{eff} of an infinite uniform medium.

3.133 NEUTRON - An elementary particle having no electric charge, a rest mass of 1.67495×10^{-27} kg, and an average lifetime of 1000 s.

3.134 NEUTRON, EPITHERMAL - Neutron of kinetic energy greater than that of thermal agitation, often restricted to energies comparable to those of chemical bonds.

3.135 NEUTRON, FAST - Neutron of kinetic energy greater than 0.1 MeV but not more than a typical Maxwellian distribution with an average energy of about 1.9 MeV.

3.136 NEUTRON, INTERMEDIATE - Neutron of kinetic energy equal to or greater than 0.1 eV and equal to or less than 0.1 MeV.

3.137 NEUTRON, SLOW - Neutron of kinetic energy less than about 0.1 eV.

3.138 NEUTRON, THERMAL - Neutrons in thermal equilibrium with the medium in which they exist. At room temperature the mean energy of thermal neutrons is about 0.025 eV.

3.139 NONFAVORABLE GEOMETRY - See *favorable geometry*.

3.140 NONFISSILE FISSIONABLE MATERIAL (see FISSIBLE) - Any composition of *nuclides* capable of maintaining a *nuclear fission chain reaction* with *fast neutrons* only, provided the effective neutron production cross section ($\bar{\nu}\bar{\sigma}_f$) exceeds the effective absorption cross section ($\bar{\sigma}_a$) of the composition.

3.141 NONFISSIONABLE MATERIAL - Any composition of *nuclides* incapable of maintaining a *nuclear fission chain reaction* with *neutrons* of any energy whereby the effective neutron

production cross section ($\bar{\nu}\bar{\sigma}_f$) is less than the effective absorption cross section ($\bar{\sigma}_a$) of the composition. This definition is intended strictly for this standard.

3.142 NUCLEAR CRITICALITY ACCIDENT, PERCEIVED - Any presumed nuclear criticality accident as inferred from the observance of physical phenomena (e.g., temperature rises, over-pressures, or others) or the activation of alarm systems indicative of a criticality accident (examples that might be included are CAS, continuous air monitors, and area radiation monitors).

3.143 NUCLIDE - A species of atom characterized by its mass number, atomic number, and nuclear energy state.

3.144 OPERATION, FISSIONABLE MATERIAL - An operation using a significant quantity of fissionable material. An operation includes handling, storage, processing, and transportation.

3.145 PACKAGE - The *packaging* together with its *fissionable material* contents as presented for movement or storage.

3.146 PACKAGING - The assembly of components necessary to ensure compliance with specifications for safe containment, storage, and handling of *fissionable materials*. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, vehicle, tie-down systems, auxiliary equipment, and devices for cooling or absorbing mechanical shocks.

3.147 PARAMETER, NUCLEAR - Any physical property whose value affects the *nuclear reactivity* of a system. Nuclear parameters include the mass, density, and isotopic enrichment of *fissionable material*; the geometry, reflection, and interaction conditions of the system; and the moderation, composition, and neutron absorption characteristics of the *fissionable material* mixture and other system materials.

3.148 PARAMETER, PROCESS - Operating or processing variables directly or indirectly affecting *nuclear parameters* of *fissionable materials*. Such process parameters may include temperatures, pressures, flow rates, viscosity, elapsed times, heights, rotational velocities, electrical resistivity, electrical potential, electrical currents, pH, color, opacity, etc.

3.149 PEER - An individual who performs peer reviews, who has at least equivalent qualifications and standing, and who is independent of one or more other individuals who perform specific original work. Independent, in this case, means not involved in the performance of the specific original work to be reviewed, to the extent practical, not the immediate supervisor of individuals who performed specific original work to be reviewed, and to the extent practical, having sufficient freedom from funding considerations to ensure that the work is impartially reviewed.

3.150 PEER REVIEW - A review process for appraising and reporting the acceptability of independent and original specific work of others.

3.151 POISON, NEUTRON - A nonfissionable *neutron absorber*, generally used for criticality control.

3.152 PROMPT BURST REACTOR - A device for producing nondestructive super-prompt-critical nuclear excursions.

3.153 PROMPT CRITICALITY - State of a fissionable material system such that the prompt-neutron contribution to k_{eff} equals unity.

3.154 PROMPT NEUTRONS - *Neutrons* emitted immediately during the *fission* process.

3.155 PROTON - A stable elementary particle having a positive charge of 1.60219×10^{-19} coulomb and a rest mass of 1.67265×10^{-27} kg.

3.156 QUALITY FACTOR (QF) - The ratio of dose equivalent to absorbed dose.

3.157 QUENCHING MECHANISM - A physical process that limits an *excursion spike*. Examples are thermal expansion, or microbubble formation in a solution.

3.158 RAD - A unit of radiation absorbed dose; 1 rad = 10^{-2} J/kg of the medium.

3.159 RADIATION - In context of *criticality safety*, alpha particles, beta particles, neutrons, gamma rays, and combinations thereof.

3.160 RADIATION MONITOR - A detector to measure the level of ionizing radiation. A purpose may be to give information about dose or dose rate.

3.161 REACTIVITY - A parameter of a *fissionable* system that is proportional to $1 - 1/k_{eff}$. Thus, it is zero if the system is *critical*, positive if the system is supercritical, or negative if the system is subcritical (see *effective multiplication factor, k_{eff}*).

3.162 REACTOR, NUCLEAR - A device in which a self-sustaining *nuclear fission chain reaction* can be maintained and controlled (fission "reactor," "pile," or "core").

3.163 RECOVERY - Proposed, evaluated, analyzed, and implemented ameliorative or corrective actions to restore an intended degree of criticality safety.

3.164 REFLECTOR - Material outside a fissionable material system capable of scattering back to the system some neutrons that would otherwise escape.

3.165 REFLECTOR SAVINGS - The absolute difference between a dimension of the reflected core of a critical system and the corresponding dimension of a similar core that would be critical if no reflector were present.

3.166 REFLECTOR, SUPERNORMAL - Any material or combination of materials that offers greater neutron reflector effectiveness than an essentially infinite thickness of water (e.g., about 20 cm of water).

3.167 RELATIVE BIOLOGICAL EFFECTIVENESS (RBE) - A factor used to compare the biological effectiveness of absorbed radiation doses (i.e., rads or grays) because of different types of ionizing radiation; more specifically, it is the experimentally determined ratio of an absorbed dose of a radiation in question to the absorbed dose of a reference radiation required to produce an identical biological effect in a particular experimental organism or tissue. This term is used only in radiobiology, not instead of *quality factor* in radiation protection.

3.168 REM - A unit of dose equivalent (Roentgen Equivalent Man), replaced by the sievert. This unit, however, has not appeared in the criticality accident literature. The dose equivalent in rems is numerically equal to the *absorbed dose* in rads multiplied by the *quality factor*, and any other necessary modifying factor.

3.169 REP - An obsolete term for absorbed dose in human tissue, replaced by rad, originally derived from Roentgen Equivalent Physical.

3.170 RISK - The quantitative or qualitative expression of possible loss, usually expressed in dollars or fatalities per year or facility lifetime, that considers both the probability that a hazard will cause harm and the consequences of that event. Not to be confused with *hazard*.

3.171 ROENTGEN (R) - A unit of exposure; 1 R = 2.58×10^{-4} C/kg in air, where C is coulombs. Strictly, the roentgen applies to *x-rays* or *gamma radiation*.

3.172 SAFETY ANALYSIS REPORT (SAR) - A report that documents the adequacy of safety analysis for a nuclear facility to provide the basis for a determination that the facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations.

3.173 SAFETY BASIS - The combination of information relating to the control of hazards at a nuclear facility (including design, engineering analyses, and administrative controls), which demonstrates that the facility can be operated safely.

3.174 SHUTDOWN MECHANISM - See *quenching mechanism*.

3.175 SIEVERT (Sv) - A unit of dose equivalent; 1 Sv = 1 J/kg = 100 *rem*.

3.176 SIGNIFICANT QUANTITY - The minimum quantity of *fissionable material* for which control is required to maintain subcriticality under all normal and credible abnormal conditions.

3.177 SITE - See *installation, nonreactor nuclear*.

3.178 SOFTWARE CATALOG - A list of all software units in operation in a stated software system used for nuclear criticality safety evaluations. It identifies each software unit and states the version approved for use as of a stated date (ordinarily, the date of issue of the catalog). The access control and the scope of the software catalog are determined by the software system team.

3.179 SOFTWARE CONFIGURATION CONTROL - The systematic evaluation, coordination, verification, implementation, and documentation of software.

3.180 SOFTWARE DEVELOPER(S) - The individual(s) responsible for the actual design or modification, or both, of the software.

3.181 SOFTWARE REQUESTOR - The organization for which software is developed and which is responsible for the software requirements definition.

3.182 SOFTWARE SYSTEM - A group of related programs and data that acts in concert toward a particular purpose, has a common developing organization, and is suitable for a single set of control mechanisms.

3.183 SOFTWARE SYSTEM TEAM - The persons responsible for the software configuration control.

3.184 SOFTWARE - The instructions that determine and define the operation of an electronic computer or computer system.

3.185 SOFTWARE USER - An organization or person who uses the software.

3.186 SPECIALIST, COGNIZANT NUCLEAR CRITICALITY SAFETY - The qualified nuclear criticality safety specialist who is knowledgeable of specific facility operations, processes, and equipment, and who is assigned by installation management to provide nuclear criticality safety analyses, computations, evaluations, reviews, or audits of designs and operations for a specified nonreactor nuclear facility.

3.187 SPECIALIST, NUCLEAR CRITICALITY SAFETY (NCSS) - That professional personnel charged with implementing programs identified in this standard.

3.188 SPIKE (IN A PROMPT-POWER EXCURSION) - The initial power pulse of a *prompt-power excursion*, limited by the *shutdown mechanism*.

3.189 STORAGE (Also "External storage") - A portion of a computer system where software and data are stored. Typically, storage is on magnetic disks, but other media may be used where appropriate. Storage may be on-line or off-line (external) to the computer operating system.

3.190 SUBCRITICAL - See *nuclear fission chain reaction*.

3.191 SUPERCRITICAL - See *nuclear fission chain reaction*.

3.192 SYSTEM ADMINISTRATOR - An individual responsible for the control of software for a defined software system, including issuance, revision, documentation, and archiving.

3.193 TECHNICAL SAFETY REQUIREMENTS (TSR) - Those requirements that define the conditions, safe boundaries, and the management or administrative controls necessary to ensure the safe operation of a nuclear facility and to reduce the potential risk to the public and facility workers from uncontrolled releases of radioactive materials or from radiation exposures due to inadvertent criticality. A TSR consists of safety limits, operating limits, surveillance requirements, administrative controls, use and application instructions, and the basis thereof.

3.194 UNCERTAINTY - Lack of absolute precision, accuracy, or sureness of actions characteristic of measurements of data, approximations of results, or execution of procedures.

3.195 URANIUM ENRICHMENT (ENRICHMENT) - The weight percentage of ^{235}U in uranium, provided that percentage exceeds its natural value; if the reference is to enhanced ^{233}U content, "^{233}U enrichment" should be specified.

3.196 VALIDATION, CALCULATIONAL METHOD - The establishment of the bias and calculational uncertainty in the results produced by the combination of the computer software, computer hardware, the data libraries, such as neutron cross sections, and the modeling method employed. The bias is established by correlating the results of criticality experiments with results obtained for these same systems by the method being validated. Commonly the correlation is expressed in terms of the values of k_{eff} calculated for the experimental systems, in which case the bias is the deviation of the calculated values of k_{eff} from the experimentally determined value. However, other parameters may be used. The bias serves to normalize a method over its areas of applicability so that it will predict critical conditions within the limits of the uncertainty in the bias. Generally, neither the bias nor its uncertainty is constant; both should be expected to be functions of composition and other variables. NOTE: Validation is not a required part of a *verification test*.

3.197 VERIFICATION, SOFTWARE CONFIGURATION CONTROL - The periodic execution of software to determine if unauthorized and undocumented changes thereto have been made.

3.198 VERIFICATION TEST - The testing of new or revised software stored in the *migration storage area* before the software is transferred into the *production storage area*. It is coordinated by the *software system team* assisted by the developer and others as required to test the unit integration, qualification, and acceptance of the software. The extent of the verification test is determined by the software system team based on the magnitude of the change and the consequences of a software failure in service.

3.199 X-RAY - Electromagnetic radiation of wavelength in the range 10^{-10} cm to 10^{-6} cm emitted from outside the nucleus.

4. GENERAL GUIDANCE. The standard establishes DOE nuclear criticality safety interpretation and guidance for consistent implementation of nuclear criticality safety (NCS) across the DOE complex. This standard is not intended to contain an exhaustive compilation of nuclear criticality safety requirements for every situation. However, the standard is intended to serve as an example for the development of detailed nuclear criticality safety procedures and manuals for DOE contractors. The implementation of this standard is the responsibility of DOE contractor design, operating, technical support, and oversight organizational units, as applicable.

4.1 APPLICABILITY. Applicability of the requirements of this standard spans design, construction, operation, maintenance, and decommissioning of covered facilities. It is recognized that the design and as-built configuration of some existing facilities do not meet all of the requirements and recommendations of this standard because they were built prior to the development of certain DOE Orders. Where practicable, currently existing operations, systems, and facilities that do not satisfy the standard requirements should be upgraded. The practicability of such upgrades should consider the cost versus the benefits. Assuming cost effectiveness, upgrades of a currently existing operation, system, or facility should be implemented if they improve nuclear criticality safety even if they may not result in complete compliance with this standard.

4.2 INTERPRETATION OF THE STANDARD. The Office of Nuclear Safety Policy and Standards (USDOE Headquarters Environment, Safety and Health - EH-31) is the cognizant organization responsible for the preparation, maintenance, and interpretation of this standard.

4.3 MAINTENANCE OF THE STANDARD. Maintenance and revision of this standard shall be in accordance with DOE Order 1300.2A, "Department of Energy Standards Program."